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Design, Dirt and Disposal: Influences on the maintenance of vacuum cleaners☆

L. Harmer [a, *], T. Cooper [b], T. Fisher [c], G. Salvia [b, d], C. Barr [b]

[a] Loughborough Design School, Loughborough University, Loughbourgh, UK
[b] School of Architecture, Design and the Built Environment, Nottingham Trent University, Nottingham, UK
[c] School of Art and Design, Nottingham Trent University, Nottingham, UK
[d] Dept. of Architecture and Urban Studies, Politecnico di Milano, Milan, Italy

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ABSTRACT

This paper explores the relationship between people's feelings about dirt, and an apparent reduction in the lifetime of vacuum cleaners. The short life-spans of vacuum cleaners is a significant environmental issue. In addition to the waste generated, they have an impact on climate change: vacuum cleaners account for the second largest embodied greenhouse gas emissions of electrical goods in the UK after televisions, largely because of their high sales volumes.

Drawing from qualitative and quantitative research undertaken for the UK Department for Environment, Food & Rural Affairs (Defra), the paper demonstrates that one motivation for vacuum cleaner replacement is the increased enjoyment from dirt removal that a new vacuum cleaner may provide. The paper also shows that premature disposal can occur once a product becomes dirty and visually damaged, and whilst functional, is perceived to be less effective. Solutions to premature disposal were explored through the co-creation of design concepts and design features were tested via an online survey.

Vacuum cleaner users were clustered into four cleaner types; Spartan, Minimal, Caring and Manic. Overall, respondents reported that improving the ease of maintaining vacuum cleaners would be the most effective way to help them to increase their vacuum cleaner's longevity. Across all cleaner types maintenance levels were low, although Caring and Manic cleaners were significantly more likely to undertake such tasks. Motivations for disposal were similar across cleaner types and we found no evidence that Caring and Manic cleaners disposed of their machines earlier because they were 'worn out.'

We discovered that Caring and Manic cleaners spend the most on their vacuum cleaners, vacuum more often and are the most likely to replace their machine after the shortest period. Those willing to do 'a lot more' to help the environment were significantly more likely to want to 'keep the floors in my home spotlessly clean' and significantly more likely to indicate that they preferred their vacuum cleaner to look new. Consequently, the paper proposes that design interventions to increase vacuum longevity should be targeted toward Caring and Manic cleaners and concludes with key design recommendations for these two cleaner types.

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1. Introduction

Every year around two million tonnes of electrical and electronic equipment (EEE) are discarded by householders and companies in the UK (HSE, 2018). Vacuum cleaners have widespread ownership in the UK: 87% of the population own at least one (MINTEL, 2010). Sustainable consumption requires increased product longevity (Cooper, 2000), not least because the fast throughput of consumer goods adds to the threat of climate change due to embodied greenhouse gas emissions (Allwood et al., 2012). Longer product lifetimes are also an integral part of the waste reduction agenda (HM Government, 2013). The environmental implications of repairing or replacing a vacuum cleaner are linked directly to frequency of use and its energy rating (Pérez-Belis et al., 2017). Research by Gallego-Schmid et al. (2016) predicts that the

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* Corresponding author
E-mail address: l.a.harmer@lboro.ac.uk (L. Harmer).

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2013 European Commission ecodesign requirements for vacuum cleaners could reduce their environmental impact by 37–44%. As they postulate, after implementation of the directive, more energy efficient vacuum cleaners and limited availability of some raw materials will strengthen the environmental argument for increasing vacuum lifetimes and managing end-of-life through circular business models (Bakker et al., 2014).

Vacuum cleaners are regularly replaced: over a three year period, 44% of UK households bought a vacuum cleaner, making it the second most frequently bought domestic appliance (MINTEL, 2013a). They are the second largest source of embodied emissions among electrical products in the UK (Product Sustainability Forum, 2012), and consumers, on average, expect them to last only 5 years (WRAP, 2013a); indeed 28% of vacuum cleaner purchases in 2012 were to replace a vacuum cleaner under that age that were reported to have broken down or proved unreliable (WRAP, 2013b).

Understanding the factors that shorten the longevity of vacuum cleaners therefore deserves further investigation. Research by the European Commission's Joint Research Council used life cycle analysis to show that "extending the lifetime of vacuum cleaners generally implies benefits for both environmental and economic perspectives for most scenarios considered" (Bobba et al., 2015: p2).

Vacuum cleaners are mature products, having evolved over the past 100 years. Manufacturers have sought to offer new purchase incentives and development has followed changes in users' lifestyles and aspirations, focusing on innovation in ease of use and saving time, whilst prices in real terms have fallen dramatically (Which?, 2017a,b).

This paper investigates the complex factors affecting the lifespan of vacuum cleaners by reporting on the research undertaken as part of a larger project, *Dirt, Damage, Servicing and Repair of Vacuum Cleaners* (Cooper et al., 2016). Such 'real world research' (Robson, 2011) works simultaneously with the material factors that shape designs and the cultural matters that make these relevant to people. Both are in play in this paper, so the relationship of users to dirt and vacuum cleaners is contextualised and the findings discussed with reference to the social sciences.

The paper explores four dimensions of the relationship of users to dirt and vacuum cleaners - *The Experience of Using and Maintaining a Vacuum Cleaner, The Cleanliness of the Home, The Dirt Inside the Vacuum Cleaner, and The 'Clean Look' of the Vacuum Cleaner* – and the implications for the repair and disposal of vacuum cleaners. After setting out the objectives and reviewing these areas, the paper describes the rationale for the research methodology and outlines the characterisation of four types of cleaner (i.e. user), who negotiate cleaning in different ways. Findings from the empirical research are then outlined, structured around the dimensions and the implications for repair and disposal. Design features that could counter the premature disposal of vacuum cleaners are then explored in relation to the characterised cleaner types.

2. Objectives

The *Dirt, Damage, Servicing and Repair of Vacuum Cleaners* project involved researchers in seeking to learn about vacuum cleaner design, use, repair, maintenance and disposal. This paper addresses three of the project's objectives; to identify vacuum cleaner users' relationship with dirt and their cleaning habits; to assess how this relationship affects product life-spans; and to explore whether design features could increase longevity by improving the users' experiences of removing dirt.

3. The relationship of users to dirt and vacuum cleaners

3.1. The experience of using and maintaining a vacuum cleaner

From Hoover's advertisements in the early 1920s to the more recent G Tech commercials, the vacuum cleaner has been advertised to appeal to the reluctant cleaner by suggesting that it creates enjoyable experiences where once there was only cleaning drudgery, offering 'liberation from domestic chores' (Stoppani, 2011: p57).

Ever since their invention, vacuum cleaners have been sold on the ease and effectiveness of removing dirt that they offer, alongside the aesthetics of cleanliness and newness (Harmer et al., 2015). As machines, they have been envisaged as almost 'magic' items for cleaning. Jackson (1992) reports on advertisements promoting the first vacuum cleaners, quoting one from the 1920s, suggesting that they offer "easy, effortless cleaning of every nook and corner" and provide for "leisure and freedom." Jackson concludes "this reveals something of the mythology of the 'mechanical servant': it is as if the vacuum cleaner steers itself around the house unaided" (Jackson, 1992, p. 166). According to Douglas (1966), people want to be pure and seem to enjoy the processes of purification that might make them so. Even so, it is possible to interpret cleaning without the assistance of technological magic as not enjoyable but mere drudgery, akin to service or subjugation.

Schifferstein and Zwartkruis-Pelgrim (2008) assert that creating an enjoyable experience is a principal method of enhancing emotional attachment to a product, and those to which we are most attached are liable to be the ones we keep for longer. They describe product pleasure as rooted in a combination of product meaning, monetary value and utility, and product attachment as the strength of the bond that these factors create, i.e. how willing we are to keep a product. Factors influencing shorter vacuum cleaner lifetimes are clearly complex (Salvia et al., 2015). However, the connection between enjoyable product experience, emotional attachment, product maintenance and longevity suggests that one factor in the relatively short lifetimes of modern vacuum cleaners is that they are either not as enjoyable to use as promised, or that any positive experience (i.e. satisfaction) of usability or removal of dirt does not last.

In this paper we make the distinction of product experiences that are enjoyable as fulfilment during the task (Schifferstein and Zwartkruis-Pelgrim, 2008) and satisfaction as fulfilment after the task (Churchill Jr and Surprenant, 1982). Whilst adverts might portray the task of vacuuming with a 'mechanical servant' as enjoyable, it is perhaps understanding satisfaction, as a longer, reflective attribute, that offers greater potential for increasing emotional attachment and thereby promote vacuum cleaner longevity. MINTEL (2010) ranked the factors consumers reported to influence the purchase of a new vacuum and revealed that after suction power (a proxy for effectiveness of dirt removal), these relate closely to an enjoyable experience: vacuum cleaners should be easy to move around (2nd) and lightweight (3rd).

3.2. The cleanliness of the home

Dirt challenges the body's margins, and its effective removal is a means to avoid disgust (Rozin et al., 1993), as well as satisfying social norms. Whilst vacuuming might be considered a chore, the removal of dirt can be both satisfying and enjoyable because there is pleasure to be had in protecting the self from contamination and thereby creating an appropriate social face. Enjoyment may also come from the physical movement necessary in using a vacuum cleaner and the visible, instant rewards of removing dirt. There is on completion, satisfaction: a home with a visibly clean carpet with

its neat brushed pile and (for the social face) suitable for the reception of guests.

In the practice of home cleaning, dirt is a focus for complex, overlapping and sometimes contradictory concerns that are deeply embedded in our culture (Fisher et al., 2015). For example, dirt may be understood both as a danger to health and a mark of social incompetence and low status. The dust that vacuuming seeks to capture has material qualities: it sticks to human skin, gets up noses, covers surfaces of objects and clouds the air - material effects that stimulate a desire to remove it. Theoretical approaches to dirt may emphasise either its material or cultural aspects. The influential position developed by Douglas (1966) suggests that its material properties and health implications are less significant stimuli for its removal than the socio-cultural system that marks it out as dangerous. More recent theorists, however, have been concerned to put the 'material' back into Douglas's account of material pollution, emphasising that dirt is in reality both physical *and* symbolic (Lagerspetz, 2018). Dant and Bowles's (2003) account of the mechanics of dealing with dirt exemplifies this newer approach, emerging from the so-called 'material turn' in the humanities and social sciences (see, for instance, Pierides and Woodman, 2012). On this understanding, vacuuming is pleasurable because it is both (physically) efficacious and (culturally) 'good'.

3.3. The dirt inside the vacuum cleaner

Ever since the vacuum's inventor, Hubert Cecil Booth (ICE, 1955) reputedly demonstrated the cleaning principle by placing a handkerchief on a restaurant chair and sucking through it, the power of trapping and disposing of dirt became evident. Vacuums capture the dirt that was once inside the home, to dispose of it outside. Immediately and literally in the case of the Booth's first horse drawn vacuum cleaners, which sat outside on the street. Nevertheless, current machines still 'lock' the dirt inside them, assuring users of the effectiveness of vacuuming.

The importance of the vacuum exhaust air being clean and free from smell and dust confirms the principle of trapping dirt; a vacuum which sucks up dirt only to redistribute the dirt as finer particles undermines the machine's capabilities. The growth of bagless cleaners has also changed the user's relationship of vacuums to dirt. Dirt is no longer permanently contained, the offending material is reassuringly visible and trapped, but must also be released to be disposed of. The bagless vacuum makes it possible for the vacuum user to evidence the work they and the vacuum have done; however, contact with dirt is not over, creating new interactions with dirt, and eliciting both attraction and repulsion that are worthy of investigation.

3.4. The 'clean look' of the vacuum cleaner

From the perspective of design, Forty (1986) identifies how furniture without carving or mouldings using fused, hard materials that do not absorb dirt, were responses to the growing association in the 20th century between dirt and disease. These modernist preferences meant vacuum cleaners could be kept looking clean, intertwining the abstract rhetoric of hygiene with the actuality of performance. These were designs that not only looked clean but *were* clean: "The history of the vacuum cleaner is a good example of the commercial applications of the phobia against dirt, and of the way appearance and styling were affected by the imagery of hygiene" (Forty, 1986: p174).

As well as collecting dirt, vacuum cleaners may themselves appear dirty: they may get marked or damaged in use, or become electrostatically charged, attracting dust to their (plastic) surfaces. This loss of physical 'gloss' with age is, however, only partly responsible for products looking used: styling obsolescence also plays a part (Cooper, 2004). As early as the 1930s vacuum cleaner manufacturers regularly changed the appearance of their designs to stimulate sales, using progressive, futuristic motifs, following the lead of the automobile industry (Forty, 1986). Henry Dreyfuss's design for the 1950s Hoover Constellation perhaps exemplifies this approach, its looks inspired by the possibility of space, its movement influenced by the potential of futuristic travel using an air cushion to help levitate it. 'Newness' drives sales and the constant arrival of new models means that as a vacuum cleaner begins to look dirty it simultaneously looks dated, losing both its physical 'gloss' and its aesthetic appeal.

4. Vacuum cleaner repair and disposal

By simple logic, motivations for disposing of a vacuum cleaner are linked with motivations for purchase. Just as the potential for enjoyment (or satisfaction, at least) might motivate purchase, a vacuum cleaner that becomes less enjoyable to use is liable to be replaced. A survey by MINTEL (2010) found that 80% of people would only buy a new vacuum cleaner if their old one was broken. What constitutes being 'broken', however, is perceived in different ways (Salvia et al., 2015). Thus new machines may replace ones that would be cost effective to repair (Which?, 2014a) or are not working properly because poor maintenance has led to worn components or blocked filters.

These functional drivers for disposing of vacuum cleaners are reinforced by changes that have dramatically reduced manufacturing costs. The cost of the first vacuum cleaners imported to Britain in 1912, £25, was equivalent to a housemaid's annual wage (Jackson, 1992). According to Statista (2018) over two thirds of vacuum cleaners purchased in 2017 were under £200, a considerably lower cost in real terms. Such reduced cost increases the likelihood of psychological obsolescence (Cooper, 2004). Cooper and Mayers (2000) identified that the low cost of replacement, combined with concern that products may become 'out of date', leads some consumers to feel that they have had value from a product after a relatively short period. According to Which? (2014b), vacuum cleaners are still typically financially viable to repair up to when they are seven years old. However, extending the lifetime of 'workhorse' products such as vacuum cleaners, is complex: "*the value of repairing such products was often seen as highly questionable. Perceived inconvenience, perceived expense (of both labour and parts) and the relatively low prices of replacement products all contributed to participants' unwillingness to get workhorse products repaired*" (Brook Lyndhurst, 2011: p6). Repair may also create additional concerns for the owner, who will consider efficiency in picking up dirt against a new counterpart and whether money spent repairing a used 'dirty' machine would be better spent on a new machine with potentially increased performance.

The result is a potential gap between actual and environmentally desirable product lifetimes, whether understood as intended, ideal or predicted (Gnanapragasam et al., 2018). With high levels of ownership and a market nearing saturation, vacuum cleaner manufacturers are challenged to create new ways of triggering replacement purchases. Nonetheless, chasing further cost reductions or improving user experiences may not be the only strategy for manufacturers. MINTEL concluded that for low cost household cleaning products "brands need to encourage consumers to shift some of their focus away from 'lowest price' to looking for better value in terms of longer-lasting products" (MINTEL, 2013b).

The disposition of owners towards 'newness' may intersect with their feelings about dirt in determining the point at which a vacuum cleaner is discarded. Campbell (1992) identifies three types of

consumer motivation for buying new products: a desire to acquire a new possession; for the pristine; and for the technically improved or novel. These consumer types may each help to explain why people replace vacuum cleaners and their choice of new machine.

5. Research methodology

The research presented in this paper was undertaken through a project funded by Defra's Action Based Research Programme (reference no. EV0554) and in collaboration with a major vacuum cleaner manufacturer. The methodology drew upon action research and adopted the Double Diamond process developed by the Design Council (2006). The interviews, focus groups and co-creation research, summarised below, were conducted in Nottingham and the surveys conducted nationally.

5.1. Action Based research

Defra's Action Based research programme sought to engage industry and research institutions in participatory and practical ways to find solutions to influence consumer behaviour toward more sustainable practices. The timescales of the project meant that it was not possible to adopt fully an action research approach (Kemmis et al., 2013) however it did inform a methodology driven by an extensive ethnographic investigation of user practices. Through which motivations for premature vacuum cleaner disposal were explored by working primarily with users but also with insights from a vacuum cleaner repairer and the collaborating manufacturer.

Through the initial project stages, it became apparent that the relatively short life of many vacuum cleaners could be treated as a design problem and addressed within a design process. However, the feedback and iterative loops of an action research approach were used and, whilst it was not possible to measure changes in behaviour through the testing of prototypes, underlying user motivations to behaviour change were sought through both theoretical and practical means. Denscombe (2014) notes that action research can be used to create guidelines for effective practices, and a toolkit aimed at manufacturers was therefore produced as a project output.

5.2. Double Diamond design process

The Double Diamond Design Process was selected as a clear, graphical way to structure the project research methods to consider the design of the vacuum cleaner in relation to purchase and disposal motivations. In line with the Design Council's recommendations, the 'Discover' phase sought to identify user needs through market and user research. The 'Define' phase interpreted these user needs into business objectives to clarify the problem: i.e. the current saturated market requires a large turnover of product in order to be profitable resulting in increased environmental impacts. The 'Develop' phase co-created design features and investigated purchasing models, and the 'Deliver' phase created refined concepts and the toolkit.

5.3. Research methods

The research utilised mixed methods for collecting primary data, including interviews, focus groups, workshops and two national surveys. A variety of vacuum cleaner design features were generated by engaging manufacturers, users and design students in seeking commercially attractive solutions to the problems identified. The research sought to collect qualitative insights about purchase, use and disposal that could be developed into features to be tested using a quantitative survey. The methods and their application in the project are summarised below (Table 1).

The mapping of these methods onto the Double Diamond process is shown in Fig. 1. The Discover stage involved three methods (A-C) to investigate and understand the relationship of users to cleaning, dirt and their vacuum cleaners. The Define stage used an online survey (D) to explore whether insights revealed by households in the Discover phase (relating to vacuum cleaner longevity) were representative of the UK population.

The Develop phase drew upon findings from the online survey (D) on attitudes and behaviour towards cleaning and dirt. In addition, using insights from users and manufacturers (B), design features were created through iterative 'co-creation' methods (E, F). Whether the proposed design features resonated in a larger population was explored through a second online survey (G), and consumers' responses were then discussed in interviews with industry stakeholders (H). The output of the Deliver phase – the 'solution' of the project – was delivered in the form of a toolkit.

Table 1
Research Methods discussed in this paper and used in the 'Dirt, Damage, Servicing and Repair of Vacuum Cleaners' project (Cooper et al, 2016).

Research Method	Detail	Purpose
A. On-street user interviews (n = 114)	Face-to-face street questionnaire conducted in Nottinghamshire with owners of vacuum cleaners responsible for maintenance and upkeep of their vacuum, covering vacuum ownership and cleaning practices.	*Scoping of consumer issues relating to vacuuming and product longevity.*
B. In-depth user interviews (n = 7) and interviews with a vacuum cleaner repairer and a manufacturer	Users selected from on-street interviewees were interviewed in their homes about cleaning practices. Local repairer and manufacturer interviewed at their premises.	*Identification of consumer issues relating to vacuuming, product longevity and disposal.*
C. Vacuum cleaner teardowns (n = 12)	'Discarded' vacuum cleaners obtained from a range of sources, including interviewees, recycling centres and trade-ins. Complete teardown and testing.	*Identification of technical issues relating to product longevity and vacuum disposal.*
D. First survey (n = 507)- *see* Appendix 1&2	Survey of UK households conducted using an on-line panel.	*Investigation of findings from stages A-C to see if they are reflected in a larger sample.*
E. Co-creation session (n = 30) - *see* Appendix 3&4	Conducted at Nottingham Trent University. Participants recruited across cleaning types.	*Generation of design concepts to increase vacuum cleaner longevity with consumers.*
F. Focus group (n = 15)	Conducted at Nottingham Trent University. Participants recruited across cleaning types.	*Review and development of concepts for vacuum cleaner longevity with consumers.*
G. *Second survey* (n = 552) - *see* Appendix 5	Survey of UK households conducted using an on-line panel.	*Review of concepts with large sample of consumers to understand if design features are appropriate.*
H. Stakeholder interviews (5 vacuum cleaner manufacturers and one repairer) - see Appendix 6	Stakeholders sent outputs and proposals from second survey prior to semi-structured telephone interviews.	*Discussion of consumers' response to concepts and design features with stakeholders to understand commercial strategies for longevity.*

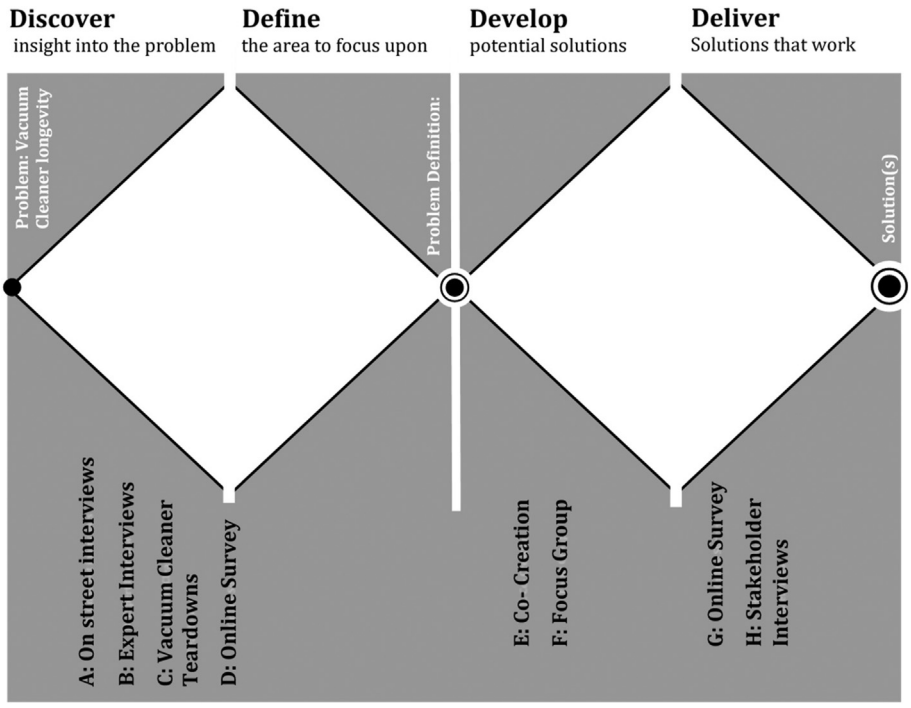

Fig. 1. Mapping of research methods discussed in this paper onto the Double Diamond Process (Design Council, 2006).

5.4. Clustering types of cleaners

Vacuuming experiences need to be contextualised within wider cleaning practices. Enjoyment of cleaning tasks and the satisfaction gained from them may have an impact on the motivation vacuum cleaner owners have to keep their homes clean, which in turn influences efforts made and time spent. Vaussard et al. (2014) investigated these motivations in the Swiss context and identified four types of cleaner based on habits: the Spartan, the Minimalistic, the Caring and the Manic. As we wanted to consider whether these cleaner types influence decisions relating to vacuum cleaners, we established a clustering process for defining cleaner types readapting Vaussard's model (simplifying the term Minimalistic to Minimal) for our survey work. Focus group participants and interviewees were recruited from the on-street interviews and we then completed the cleaner clustering process outlined in Fig. 2 to assess cleaner type.

Only owners of vacuums were permitted to answer the surveys. In the first online survey questions covered demographics, attitudes towards the environment and a range of questions about their vacuum cleaner and cleaning practices and the importance of cleanliness. This made it possible to assign almost all respondents (96%) to one of the four groups, spread as follows: Spartan cleaners (12%), Minimal cleaners (34%), Caring cleaners (40%) and Manic cleaners (10%). These cleaner types were identified and used in subsequent stages of the project.

5.5. Identifying suitable cleaner types for longevity design concepts

The process for identifying consumers most appropriate to engage with longevity strategies through design interventions is shown in Fig. 3. In addition to being asked about their cleaning practices, survey respondents were asked about vacuum ownership and their environmental opinions. Cleaner types were then compared, with reference to frequency of vacuum replacement and whether they would like to do more to help the environment.

6. Findings

This section considers, in turn, findings related to the four dimensions of the relationship of users to dirt and vacuum cleaners discussed earlier and the implications for the repair and disposal of vacuum cleaners. Themes that emerged in the empirical work are explored in the context of selected studies in the human sciences in order to understand how different cleaner types relate to cleaning and dirt and the disposal of vacuum cleaners. A generalized comparison of the findings to cleaner types listing the relationship dimensions and user attitudes and behaviour is shown in Table 2.

6.1. The experience of using and maintaining a vacuum cleaner

Enjoyment and satisfaction gained from vacuum cleaning was explored in several phases of the research. During the on-street interviews all types of cleaners reported that they gained satisfaction from vacuuming. However, the first online survey revealed that many people do not regard cleaning the home as an enjoyable (or even engaging) task, with nearly 40% of respondents wishing that someone else would clean their home.

The co-creation workshop explored vacuum cleaner users' cleaning experiences, particularly in relation to prolonging a machine's lifetime. Participants were invited, in teams, to draw upon their own experience to describe their most enjoyable and most frustrating vacuum cleaners. Similarities existed across all teams. Participants indicated that they considered vacuum cleaning most enjoyable when using a machine that is easily manoeuvred (e.g. lightweight and cordless), user-friendly (e.g. easy to take apart), adaptable (including accessories), powerful (e.g. high suction performance), appealing (e.g. smooth aesthetic and sensible price) and which requires low maintenance (e.g. easy to empty and repair). By contrast, vacuum cleaning was most frustrating when the machine was difficult to manoeuvre (e.g. heavy, wobbly or unstable), not user-friendly (e.g. noisy or difficult to store), required complex maintenance tasks (e.g. emptied from the bottom and requiring

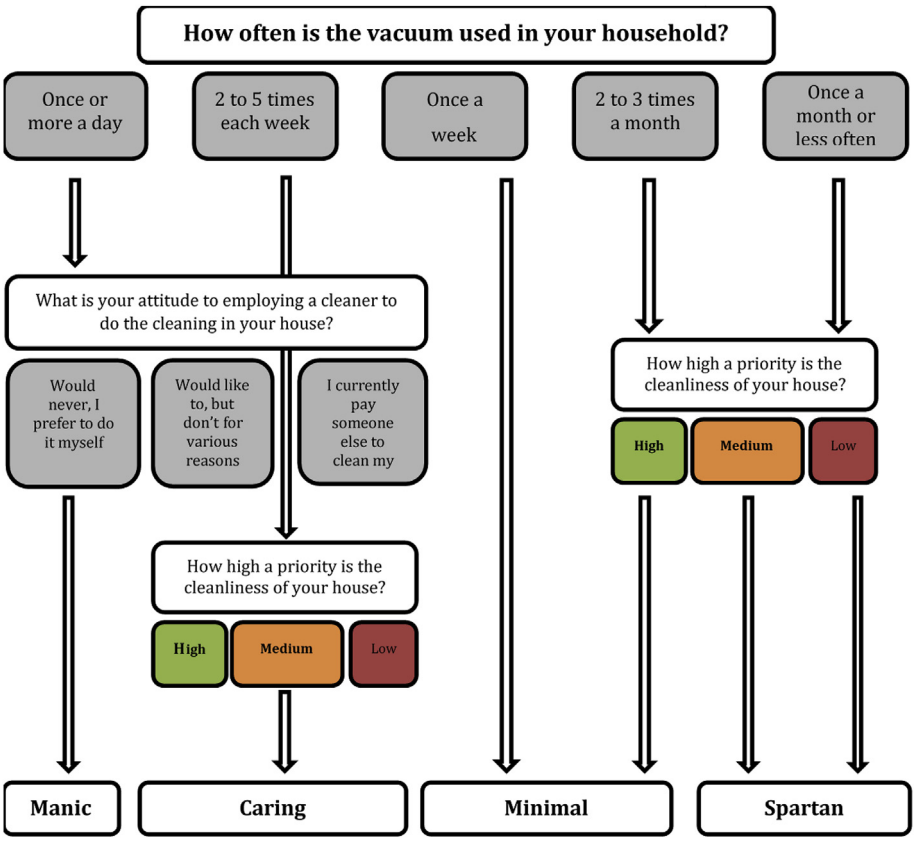
How often is the vacuum used in your household?
Once or more a day
2 to 5 times each week
Once a week
2 to 3 times a month
Once a month or less often
What is your attitude to employing a cleaner to do the cleaning in your house?
Would never, I prefer to do it myself
Would like to, but don't for various reasons
I currently pay someone else to clean my
How high a priority is the cleanliness of your house?
High
Medium
Low
How high a priority is the cleanliness of your house?
High
Medium
Low
Manic
Caring
Minimal
Spartan

Fig. 2. Clustering of survey respondents into the 4 cleaner types based on attitudes and cleaning behaviour.

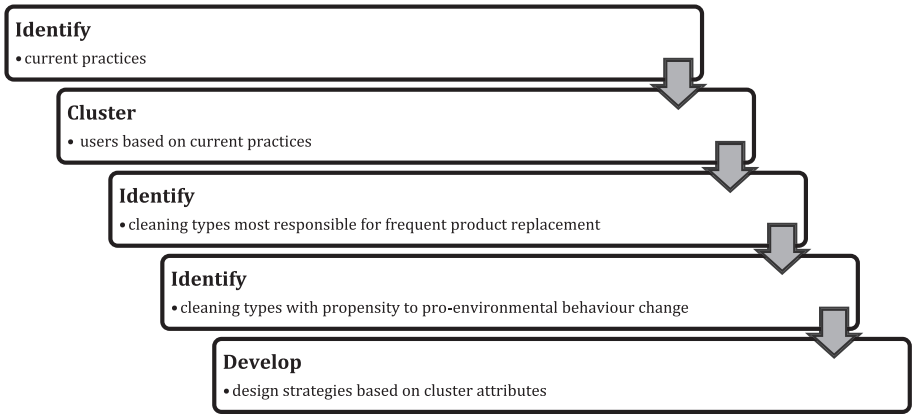

Fig. 3. Identifying impact areas for increasing longevity.

that hair be disentangled from the brushes), lacked suction power, or was visually bulky and attracted dust and scratches.

The user interviews discovered users who not only felt satisfied after vacuuming but actively enjoyed it, mirroring the historic advertisements that showed cleaning as enjoyable and effortless (Jackson, 1992). One Manic cleaner interviewee purported to vacuum clean every day in order to relax after work. At the other end of the spectrum, the main aim of Spartan cleaners when vacuuming was to complete the task in the shortest time possible. They barely notice dirt and do very little about it (Fisher et al., 2015). Spartan cleaners do not seem to enjoy vacuum cleaning: in the survey more than half reported that they would like to employ someone to clean their home.

There was evidence from the first online survey that some users do not undertake even the most rudimentary of maintenance tasks on their machine. While 5% of respondents change or clean the filter regularly, 13% either do not ever clean their filters or do not know if their vacuum cleaner has one (29% in the case of Spartan cleaners), and around a fifth (18%) wait until it 'does not suction properly'. This reveals a low level of knowledge about the fundamental components of a vacuum cleaner and its basic maintenance requirement. Apart from emptying the vacuum cleaner and cleaning or replacing filters, one in six respondents (16%) do not carry out other maintenance tasks such as ensuring the brush head is free of hair or dirt and removing dust from around the casing. The proportion is significantly higher in the case of Spartan cleaners than

Table 2
Generalized comparison of cleaner types with relationship dimensions and user attitudes and behaviour from the first online survey (D) and second online survey (G).

Cleaner Type	Relationship dimensions *(D)*				User attitudes and behaviour		
	The Experience of Using and Maintaining a Vacuum Cleaner	The Cleanliness of the Home	The Dirt Inside the Vacuum Cleaner	The 'Clean Look' of the Vacuum Cleaner	Maintenance *(D)*	Disposal *(G)*	Environment *(D)*
Spartan	*Dislikes cleaning*	*Low to medium priority - vacuums once a month or less*	*Doesn't mind contact with dirt*	*Unconcerned about wear*	*Unconcerned about efficiency, very low maintenance*	*Infrequent disposal*	*Lower environmental concern*
Minimal	*Cleaning seen as a necessity*	*Medium priority - vacuums two to three times a month*	*Accepts contact with dirt*	*Doesn't mind some wear*	*Some concern about efficiency, low maintenance*	*Less frequent disposal*	*Low environmental concern*
Caring	*Cleaning seen as a necessity, some enjoyment*	*Medium to high priority - vacuums two to five times a week*	*Tolerates contact with dirt*	*Likes vacuum to look new*	*Concerned about efficiency, more maintenance*	*More frequent disposal*	*High environmental concern*
Manic	*Enjoys cleaning*	*High priority - vacuums more than five times a week*	*Avoids contact with dirt*	*Requires vacuum to look new*	*Concerned about efficiency, higher maintenance*	*Frequent disposal*	*Higher environmental concern*

Caring or Manic cleaners (31% cf. 10% and 8%, respectively, $p < 0.05$).

6.2. The cleanliness of the home

The first online survey findings helped to explain people's attitudes and behaviour towards cleaning their homes, thereby indicating their reaction to the presence of dirt in the home. It revealed that 64% of respondents were the main user of the vacuum cleaner while just under a quarter (23%) shared this responsibility. In other cases, a partner or spouse (10%) or another adult (2%) was the main user. Around three-quarters of respondents either use their vacuum cleaner 2 to 5 times a week (41%) or once a week (33%). At the extremes, 13% vacuum once or more a day, while 4% vacuum only once a month or less often. The other 10% vacuum 2 or 3 times a month.

Cleanliness in the home is a 'high priority' for nearly a third of respondents (31%), while the majority (59%) rate it as a 'medium priority' and 10% a 'low priority'. This aligns with research by MINTEL (2013a), which concluded that nearly three quarters of adults in the UK 'really care' about their home being clean, taking pride in maintaining a clean home. The priority put on home cleanliness relates to frequency of vacuum cleaning and, to some extent, attitudes to the environment; respondents willing to do 'a lot more' to help the environment were significantly more likely to strongly agree that 'it is really important to me that I keep the floors in my home spotlessly clean to ensure the well-being of my family/household' than those willing to do 'a bit more', or 'happy with what I do' (39% cf. 15% and 17% respectively, $p < 0.01$).

Over two thirds of respondents agreed (46%) or strongly agreed (21%) that keeping floors 'spotlessly clean' in their home is important to ensure the wellbeing of their family/household, consistent with findings from MINTEL (2013). Only 8% either disagreed or disagreed strongly. Cleaning the home is usually an activity carried out by household members; only a very small proportion of respondents (4%) currently pay someone else to help clean their home. Although 60% would never consider employing a cleaner, around a third (35%) do not employ a cleaner but would like to, suggesting that they regard cleaning as unenjoyable.

6.3. The dirt inside the vacuum cleaner

All cleaner types vacuum the same kind of physical dirt, but they vary in how sensitive they are to it. Attempts to limit contact with dirt are greater with Manic cleaners, as demonstrated in responses from the first online survey (Fig. 4). User interviewees reported having dust allergies, suggesting a greater concern about the wafting dirt that the vacuum cleaner is designed to control. When emptying bags or canisters, this undifferentiated matter will fly around and may enter their noses and make them sneeze. The visibility of dirt (especially with bagless cleaners) was considered both positive and negative. For some, it increased the enjoyment of vacuuming and they reported a sense of satisfaction and achievement at being able to see dirt collected. Several of our interviewees reported how they took care to avoid contact with dirt when emptying their vacuum cleaner**s.**

The user interviews suggested that the sense of disgust engendered by the dirt that vacuum cleaners capture may have a role in their disposal. One interviewee, a Caring cleaner, commented on keeping their vacuum cleaner free from dirt: *"It's the thought I suppose of all that dirt just sitting there, and if there was a piece of food that accidently got sucked up, rotting away inside there … urghh … getting stinky."* A machine that is simultaneously dirty on the outside and reveals dirt captured on the inside may need only relatively minor mechanical problems or external damage to prompt replacement. Indeed, one vacuum cleaner manufacturer suggested that *"the growth of bagless products … has promoted the perception of products being unclean and the early disposal of products as a consequence."*

6.4. The 'clean look' of the vacuum cleaner

The first online survey investigated users' responses to the loss of their vacuum cleaners' physical 'gloss' with use or age. Only 10% of respondents reported dissatisfaction when their machine gets marked or chipped. Nearly half (47%) prefer it to look new but 'tolerate' visible signs of wear, while 43% 'do not care' if it shows signs of wear; vacuum cleaners are generally not displayed but kept out of sight in a cupboard (62%) or hidden from view in other ways, such as behind a door or sofa (17%). Manic (60%) and Caring (59%) cleaners were significantly more likely to indicate that they preferred their vacuum cleaner to look new but tolerate visible signs of wear than Spartan (34%) and Minimal cleaners (34%) ($p < 0.05$). A scratched or dirty casing could lead to disaffection, particularly amongst Caring and Manic cleaners, even to the extent of encouraging disposal of vacuum cleaners that are still functional; disaffection is particularly likely for products with connotations of hygiene (Fisher and Shipton, 2009; Fisher, 2004). Around one in six respondents (16%) replaced their vacuum cleaner because they 'wanted a new one' despite their existing one still working, suggesting that a vacuum cleaner might be perceived as a disposable object that does not warrant time, money or effort.

Some cleaners in the user interviews noticed their machine was looking 'used'; one of them expressed a desire for something 'new and shiny'. Several of those who had more than one vacuum cleaner

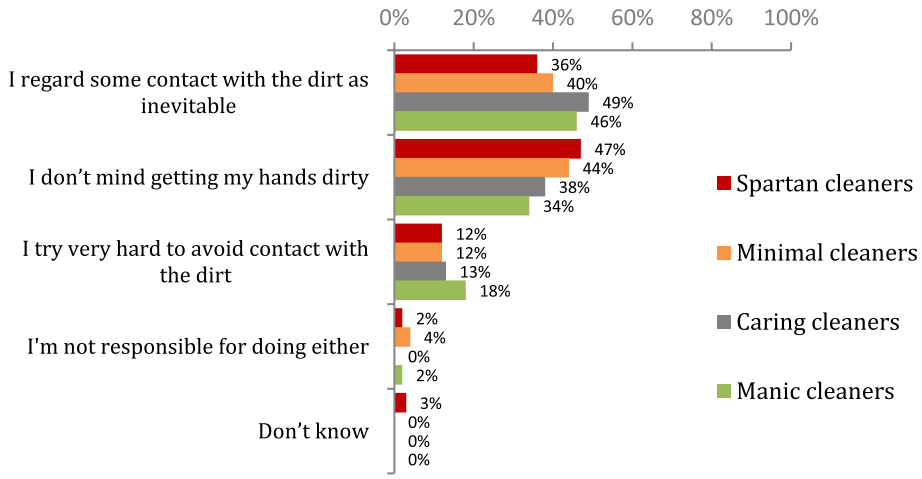

Fig. 4. Response to question "How do you feel about contact with the dirt when either changing the bag/emptying the container or when cleaning the head of your vacuum?" Base: Spartan cleaners (59), Minimal cleaners (174), Caring cleaners (205), Manic cleaners (50).

kept the less favoured one out of sight, in a cupboard or shed, suggesting that as the look of a machine deteriorates with use it may be hidden away, and that dirt may have a role in disposal decisions.

The teardowns illustrated how the plastic materials used in modern vacuum cleaners show 'wear' in characteristic ways, with implications for longevity. Plastics are relatively soft, allowing the surface of a vacuum cleaner to acquire scratches and grazes; plastics that start life shiny and transparent become dull and opaque. The electrostatic properties of plastics mean that the very fine dust that vacuum cleaners collect is attracted to the surfaces of casings, which are often made in complex shapes that are not easy to clean.

The 'hygienic design' rhetoric of the machines that Forty (1986) identified remains significant and may have consequences for their longevity, overlapping with current aesthetic aspects in vacuum cleaner designs. Convoluted moulded plastic details characterise the design language used to signify technical advancement, drawing from science fiction, but harbour dirt, and the fragility of mouldings observed in the teardowns invites rapid physical deterioration. On inspection, used vacuum cleaners were often covered with a fine dust through static attraction, and the materials and design features meant that the visual degradation could only be rectified by replacing major plastic components. This aesthetic ageing, the physical contamination involved in vacuuming and the moral frame described earlier could be classed as different components of 'dirtying': as Forty put it, "pollution is a matter of aesthetics, hygiene or etiquette" (1986: p73).

Dirt, visual damage and ageing aesthetics are all factors implicated in premature disposal (Fisher et al., 2015). It therefore follows that one way to increase longevity would be to use more robust materials and more timeless visual design. Whilst participants in a focus group convened to develop and refine such strategies they were somewhat indifferent to the concept of 'timeless design' of vacuum cleaners, but were positive towards increased attachment and achieving product longevity by tackling users' lack of enjoyment in vacuum cleaning.

Campbell's (1992) 'neophile' purchase motivation is reflected in the 16% of all cleaner type respondents who replaced their last vacuum cleaner because they 'wanted a new one'. Around one in seven (14%) survey respondents had given their previous vacuum cleaners away and an identical percentage still had them at home, confirming that many machines which are replaced are still operational, while some are kept because owners have some attachment or secondary purpose for them.

The fact that 28% of survey respondents replaced their last vacuum cleaner for reasons other than it not working at all or not working efficiently suggests that many items are disposed of because of emotional detachment, and not necessarily when they are no longer capable of undertaking their task. This was also apparent in the discarded but functioning machines observed in the product teardowns: only four of the twelve would not switch on or had no suction. Vacuum cleaners can be subject to psychological obsolescence. An interview with a manufacturer suggested that although guarantees act as important sales drivers by creating product confidence, they are not necessarily utilised by consumers in the event of product failure: *"Most of our products have 2 year warranties … some of our premium products have 6 years, but again I don't think many people use the 6 years … because designs change, fashions change."*

6.5. Vacuum cleaner repair and disposal

Most respondents would consider repairing their vacuum cleaner or getting it repaired if it developed a fault. Only a small proportion consider repair not to be worthwhile. Vacuum cleaners are not considered worth repairing by 14% of respondents if they lose suction and 11% if they do not switch on. In the event of loss of suction owners would consider undertaking the repair themselves if the fault was minor (27%) and would definitely do so if they had the necessary information and parts (26%); nearly a quarter (23%) would consider getting the vacuum cleaner repaired by someone else. Similar proportions were recorded in the event of machines not switching on. Even so, only 18% have had their current vacuum cleaner repaired, which suggests that the repair option is rarely taken. The gap between the stated attitude and performed action could be due to barriers preventing execution of the repair option in the case of failure or loss of efficiency, such as the product's design, levels of service, inconvenience and cost (Brook Lyndhurst, 2011).

The first online survey revealed that the most common reason for owners ceasing to use their previous vacuum cleaner was that it had stopped working efficiently (44%); overall, nearly two thirds of vacuum cleaners (66%) were still functioning in some manner when discarded, as distinct from not working at all. Cleaning or replacing filters is regarded by manufacturers and repairers as essential for keeping vacuum cleaners in good working order, as

indicated in instruction manuals. The proportion of survey respondents who replaced their vacuum cleaner due to reduced efficiency was relatively low for Spartan cleaners (33%), perhaps because they are less concerned about the risk of not having a machine that performs efficiently.

6.6. Design and assessment of product features

The duration of the project meant that it was not possible to trial physical design interventions. However, the second online survey was used to assess a range of potential features for increasing vacuum cleaners' longevity which had been generated with users in the co-creation session and reviewed by the focus group. Using the same criteria as in the first online survey (Fig. 2), respondents were again clustered into the cleaner type groups, with a comparable outcome (Spartan cleaners 9%, Minimal cleaners 26%, Caring cleaners 53% and Manic cleaners 10%). No significant relationship was found between gender or age and cleaner types.

Most respondents in the second survey had kept their previous vacuum cleaner for no more than 6 years. Around a third (31%) had kept it for 4–6 years, a similar proportion (32%) for 1–3 years, and a small proportion (6%) for up to a year. By contrast, nearly one in five (19%) had kept their previous vacuum cleaner for 7 or more years; One in eight (12%) could not remember how long they had kept their previous vacuum cleaner or had not owned one. Spartan cleaners (24%) were significantly more likely keep their vacuum for over 12 years than other cleaner types (Minimal 4%, Caring 4%, Manic 2%, $p < 0.05$). This confirms evidence from the first survey that those who regard cleanliness in the home as less important (i.e. Spartan and Minimal cleaners) tend to keep their vacuum cleaner for longer. Caring and Manic cleaners, who vacuum more often than Spartan and Minimal cleaners replace their machines more frequently. The proportion who only keep their vacuum cleaner for 1–3 years is significantly higher for Manic and Caring cleaners (45% and 34%, respectively) than Spartan and Minimal cleaners (12% and 29% respectively). More than a quarter of Caring cleaners (26%) had spent £200–299 on their current cleaner, a significantly higher proportion than for Minimal cleaners (15%) ($p < 0.05$), whereas a mere 4% spent less than £50, a significantly lower proportion than for Minimal cleaners (15%) ($p < 0.01$).

The product features were grouped together into four concepts for ease of questioning (Table 3). The features contained within the concepts present different ways to increase longevity that cover the four relationship dimensions: *The Experience of Using and Maintaining a Vacuum Cleaner, The Cleanliness of the Home, The Dirt Inside the Vacuum Cleaner, and The 'Clean Look' of the Vacuum Cleaner.* Respondents were asked about each feature in turn, a key aim being to evaluate whether the features would encourage them to keep their vacuum cleaner for longer. Some features directly attempted to improve enjoyment in use and the relationship with dirt (such as dirt parceling), others attempted to resolve the disconnect between perceived function and actual performance (such as an information handle). Respondents were asked about the extent to which they agreed whether a feature 'might make me want to keep this vacuum cleaner for longer.' The level of the agreement for each feature was averaged, by mean, on a scale from 1 (strongly disagree) to 5 (strongly agree) (Fig. 5).

For every feature, across all concepts, Caring and Manic cleaners indicated stronger agreement than Spartan and Minimal cleaners that it would help them keep their vacuum cleaner for longer. The design concepts and features are therefore discussed below with a focus on the Caring and Manic cleaner types.

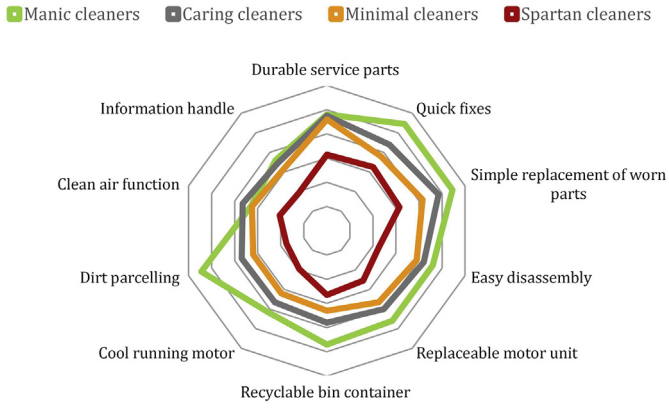

Fig. 5. Ranking of the ten preferred design features that 'might make me want to keep this vacuum cleaner for longer', by cleaner type. The grid lines represent scores for the design features, rising from 3.0 (inner line) to 4.0 (outer line) in 0.2 increments.

Table 3
Concepts and their features after development through the co-creation session and focus group.

Information Concept	Senses Concept	Emotion Concept	Convenience Concept
Colour coded maintenance parts *(for easy and quick identification and maintenance)*	**Anti-scratch and anti-static materials** *(body made from robust material designed to resist scratches and dust)*	**Clean air function** *(whilst docked acts as air purifier)*	**Easy disassembly** *(at end of life the motor and electronics are easily removed and returned to the manufacturer whilst the vacuum can be recycled with normal household plastic)*
Educational assembly *(assembly of key maintenance parts before first use-* e.g. *filters, brush-bars and belts)*	**Cool running motor** *(cooler running motor engineered to reduce smells and prolong motor life)*	**Customisable covers or casings** *(body available in a range of materials, colours and patterns to suit any home)*	**Longevity labelling** *(tells you how long critical components should last;* e.g. *motor, hose, filter and cable recoil)*
Information handle *(shows how well dirt is being picked up and when and where there is a problem)*	**Durable service parts** *(the filters and brush bar are designed to be washable and last the life of the machine)*	**Dirt parceling** *(dirt is parcelled into clean, fragrant compressed pouches for clean, allergy free disposal)*	**Recyclable bin container** *(made of lightweight recyclable plastic the bin container can easily be recycled when full – for allergy suffers or messy jobs)*
Internet enabled diagnostics *(internet connected support to arrange simple repair or replacement)*	**Quick fixes** *(the vacuum is supplied with materials, parts and instructions to make quick repairs)*	**In-home servicing** *(an affordable maintenance service whereby the manufacturer sends operatives to users' home to maintain 100% efficiency)*	**Replaceable motor unit** *(the motor unit can be returned to the manufacturer in exchange for a remanufactured unit)*
Online maintenance *(maintenance reminders, videos and tutorials delivered to your mobile device or computer)*	**Timeless and classic** *(classic, clean and functional appearance designed to age well)*	**Leave vacuum cleaner on display** *(simple, clean design, suitable for docking on a wall, visually compliments a room)*	**Simple replacement of worn parts** *(every part of the vacuum is easy to replace when required without the use of tools)*

6.7. Information concept

Within the Information concept, the *Information handle* (3.64) scored highest as liable to make respondents want to keep a vacuum cleaner for longer. It was also the feature ranked highest for overall appeal, being chosen by 40% of respondents. Females in particular found it attractive; they were significantly more likely than males to choose it (45% cf. 36%, $p < 0.05$). It scored highest for Caring and Manic cleaners (3.69 and 3.72 respectively).

6.8. Senses concept

Within the Senses concept, *Durable service parts* was the feature that scored highest as liable to make respondents want to keep a vacuum cleaner for longer (3.90), followed by *Quick fixes* (3.83). *Durable service parts* was the feature ranked highest for overall appeal (41% of respondents). *Quick fixes* had a relatively high score from Manic (4.09) and Caring (3.88) cleaners. In the case of a *Cool running motor* (3.68), Manic cleaners scored higher (3.83) than Spartan cleaners (3.39), perhaps due to an association of odour with reduced cleanliness. Unexpectedly, *Timeless and classic design* (3.35) was the feature that scored lowest for longevity, perhaps due to concern that such a product might not fit with respondents' changing home décor.

6.9. Emotion concept

Dirt parceling (3.68) was the feature in the Emotion concept that respondents scored highest as liable to make them want to keep a vacuum cleaner for longer, with Manic cleaners scoring considerably higher (4.09) than Spartan cleaners (3.35). This suggests that the feature would suit people who vacuum more often and put a higher priority on cleanliness. The feature that scored second for longevity was *Clean air function* (3.65). Females (3.63) agreed more than males (3.48) that certain features – *Clean air function*, *Dirt parceling* and *In-home servicing* – would encourage them to keep the machine for longer.

6.10. Convenience concept

Simple replacement of worn parts was the feature in the Convenience concept that scored highest as liable to make respondents want to keep a vacuum cleaner for longer (3.89). It was also the feature ranked highest for overall appeal especially amongst Manic cleaners (4.09).

Aggregating the results for Caring and Manic cleaners, the five features from among all the concepts that scored highest as liable to make owners want to keep their vacuum cleaner for longer were, in ascending order; *Easy Disassembly, Dirt Parceling, Durable Parts, Quick Fixes* and *Simple Replacement of Worn Parts.* Whilst all the relationship dimensions have a bearing on the concepts selected, four relate closely to the dimension 'Experience of Using and Maintaining a Vacuum Cleaner' and the fifth (*Dirt Parceling*) to 'The Dirt Inside the Vacuum Cleaner.'

7. Conclusion

The findings reported in this paper address the relationship between users' experiences of dirt and design interventions that could increase the longevity of vacuum cleaners. They form part of a UK Government-funded study on the repair and maintenance of vacuum cleaners.

The stakeholder interviews revealed that vacuum cleaner manufacturers develop new products and create sales by engaging with the sense of satisfaction and enjoyment that people gain by extracting dirt from their homes. The co-creation exercise demonstrated that consumers want an enjoyable experience of dirt removal and that features in new designs that appear likely to improve experiences could help drive new purchases, while the presence or visibility of dirt may encourage premature disposal. The product teardowns showed that cost-driven processes may result in machines that are more likely to be functionally and visually damaged in use, contributing to shorter product lifetimes. Both the product teardowns and consumer interviews confirmed survey evidence that vacuum cleaners are often discarded though still functional. Collectively, this illustrates that many vacuum cleaners are discarded not because they are broken beyond repair, but because users perceive a loss of efficiency or face barriers to maintenance and repair, and replacement by pristine machines with new features is affordable.

Using Vassaurd et al.'s classification of cleaner types, evidence from our surveys indicated that Caring and Manic cleaners, who vacuum more often and give a high priority to cleanliness in their home, typically spend more on vacuum cleaners, replace their machines after a shorter period and are more likely to prefer their vacuum cleaner to look new, compared with Spartan and Minimal cleaners. Maintenance levels were low across all cleaner types, but Caring and Manic cleaners were more likely to undertake maintenance tasks. Motivations for disposal across cleaner types were similar, and we found no evidence that Caring and Manic cleaners' machines were being disposed of earlier than those of the other cleaner types because they had been used more frequently.

The priority put on home cleanliness relates, to some extent, to attitudes to the environment, with respondents willing to do 'a lot more' to help the environment significantly more likely to strongly agree that 'it's really important to me that I keep the floors in my home spotlessly clean.' Caring and Manic cleaners accounted for 60% of respondents in the first survey and 63% in the second; a potentially substantial share of the market. Together, the findings suggest that Caring and Manic cleaners should be targeted in any strategy to increase vacuum longevity. For Caring and Manic cleaners, the five preferred features from all the concepts illustrate underlying concerns of not being able to maintain their machines such that they remove dirt effectively and their desire to avoid contact with dirt.

In conclusion, we propose the following five recommendations to increase vacuum longevity through design interventions and suggest that these be targeted at Caring and Manic cleaners. From the first online survey and the co-creation stages these are: 1. Design vacuums that will remain enjoyable to use over their lifetime; 2. Design vacuums that are likely to retain an 'as new' aesthetic for as long as possible (e.g. by removing superfluous detailing). From the second online survey: 3. Improve ease of machine maintenance to tackle real and perceived ineffectiveness as the machine ages; 4. Reduce contact with dirt during maintenance tasks; 5. Incorporate performance information to indicate when maintenance is required, to aid cleaning satisfaction and reassurance of the machine's ability to remove dirt.

There has hitherto been little research undertaken on the maintenance and use of consumer durables such as vacuum cleaners, despite the growing significance of product life extension strategies for progress towards a circular economy. In order to understand the effectiveness of the recommendations, a longitudinal study is suggested to trial design interventions on modified or prototype vacuums. Additionally, new business models for vacuum cleaner manufacturers require development (e.g. vacuum trade in and resale to other cleaner types) in order to understand how to make vacuum cleaner longevity attractive. Finally, the overall approach used in this project may have application in identifying effective strategies for decreasing the environmental impact and

increasing the longevity of other products. Identifying and clustering users based on their current practices and environmental attitudes could help identify and focus effective design interventions and strategies for increasing product longevity.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.04.101.

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